DEPARTMENT OF THE INTERIOR
GENERAL LAND OFFICE

THE IMPROVED SOLAR ATTACHMENT

A DESCRIPTION OF THE SMITH SOLAR ATTACHMENT AS RECENTLY IMPROVED FOR THE SURVEYING SERVICE OF THE GENERAL LAND OFFICE

WITH A STATEMENT OF THE ADJUSTMENTS

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THE IMPROVED SOLAR ATTACHMENT.

In the surveying service of the General Land Office the Smith solar attachment has been developed to a state of efficiency which has fully warranted the adoption of this model as a standard instrument for use in the public land surveys. Recent improvements have added greatly to the precision and ease with which the adjustments may be accomplished, and the following article is published for the general information of the surveyors.

DESCRIPTION.

The working parts of the Smith solar attachment consist of five fundamental features, each performing its own distinctive function The principles involved have been adapted to various types of construction, and the efficiency of the different designs is related directly to the perfection which may be attained in making a proper adjustment in the field, the stability of the adjustments when made, and the compactness of the design, considering protection to the working parts and proper distribution of weight. The five fundamental working parts consist of:

1. An auxiliary telescope whose line of collimation is the polar axis of the solar attachment; the telescope may be revolved in collar bearings which are securely mounted on a vertical limb.
2. The vertical limb is mounted on a horizontal axis and has a graduated latitude arc in its vertical plane.
3. A plane mirror at the objective end of the auxiliary telescope with an axis normal to the line of collimation, and an arm leading to a graduated declination arc.
4. An hour circle on the auxiliary telescope mounted normal to the line of collimation.
5. A set of equatorial wires parallel to the axis of the reflector.

In all the forms of construction of the Smith solar attachment the auxiliary telescope is mounted in a vertical plane parallel to the transit telescope. Thus, if the instrument is in proper adjustment and oriented to the true meridian, the polar axis of the solar attachment may be made parallel to the earth's polar axis by setting off the true latitude of the station. The sun's rays are brought into the auxiliary telescope by means of the mirror, due allowance being made for the sun's declination north or south of the equator, but to bring the sun's image into the auxiliary telescope the latter must be revolved

in its collar bearings until the reading of the hour circle agrees with the sun's apparent time. When the auxiliary telescope is thus revolved the sun's image will traverse the field of the eyepiece parallel to the equatorial wires with the limbs of the disk tangent to the same. If the transit is turned in azimuth the sun's image will immediately depart from the equatorial wires, except at noon when the image will follow the equatorial wires whether the transit be turned slightly in azimuth or the auxiliary telescope be revolved in hour angle. At apparent noon the declination arc is in a vertical plane and at this time an absolute determination may be made of the correctness of the reading of this arc.

In the improved construction special attention has been given to suitable means by which the various working parts may be properly adjusted in accordance with the principles upon which the theory of the Smith solar is founded. No detail has been omitted, and the arrangement of the working parts admits of precise and rapid adjustment in the field, in a simple manner readily understood by any competent operator, and absolutely free from any uncompensated or residual errors. Especial attention has been given to a proper distribution of the weight, to compactness, and to maximum protection to the delicate working parts.

The General Land Office surveying service has given special attention to every form of solar instrument and has constantly in use a large number of such instruments, and in this surveying work the Smith solar attachment has far outclassed all other forms of solar in efficiency and reliability. It is not the purpose here to undertake a comparison of solar instruments or a comparison of the various types of construction of the Smith solar, but to give a correct description of the improved construction and an outline of the field adjustments and operation. The evolution from the old to the new model has been a slow, tedious process, one step at a time, each change being put to the test of months of actual field use.

In the improved construction the solar attachment is mounted upon the east standard of a regular light mountain model full engineer's transit, the horizontal circle of which has a diameter of 4½ inches, with a vertical circle of 4 inches diameter. The horizontal distance between the vertical planes of the transit and auxiliary telescopes is a trifle less than 4 inches. The auxiliary telescope has a focal length of 4¾ inches and a magnifying power of about 10 diameters. The latitude arc has a radius of 3 inches, and the declination arc has a radius of 3½ inches. Upon the latter arc the graduations read the true declination and, as the mirror needs to be turned only 5° to correspond to a change of 10° in the sun's declination the graduations are made in one-half space, i. e. an interval of 10° on the arc

as graduated occupies a segment of only 5°. At zero declination the plane of the mirror is at 45° to the line of sight of the auxiliary telescope. Both telescopes are fitted with the necessary colored glass shades for observing the sun. The essential features of the important improvements over older models are here outlined:

1. The solar has been mounted upon an instrument having the U-shaped standards, thereby adding much to the stability of the attachment.

2. The base plate of the solar is mounted upon three foot posts, thereby relieving the strain due to imperfect adjustment of the older models having a four-point base.

3. The position of the base plate is adjustable by means of opposing capstan nuts on the foot posts, each with countersunk ball washer, thereby obtaining positive adjustment altogether free from strain on the capstan nuts.

4. The three-point base forms a right-angle triangle, with one side horizontal and one side vertical, thereby permitting adjustment in either of two directions: (a) One about a horizontal axis and (b) one about a vertical axis, either without disturbing the other.

5. The axis of the latitude arc is so arranged that its position may be tested with a striding level without removing the auxiliary telescope.

6. The latitude arc and auxiliary telescope are both hung underneath the latitude axis, thereby lowering the center of gravity of the attachment and giving much greater protection to the delicate working parts.

7. Suitable capstan nuts have been placed at one end of the auxiliary telescope to provide for its proper adjustment with respect to the axis of the latitude arc.

8. Improved interlocking devices have been placed on the latitude and declination arcs, verniers, clamps, and tangent motions.

9. The mirror may be swung around instantly to permit direct sighting through the auxiliary telescope.

10. Absolute freedom of motion of the various working parts, each to perform its own function, and each one independently, quickly, and permanently adjustable.

Good solar work must depend first of all upon the proper adjustment of the transit upon which it is mounted, with great care to keeping every working part cleaned, suitably oiled to work smoothly, and protected from adverse weather and injury. The same precautions are due the solar attachment. It will give very efficient meridional performance if properly adjusted and operated; nothing less can be conceded.

Before starting in with the adjustments it should be determined that the auxiliary telescope revolves smoothly in its collar bearings, neither too tight nor too loose; that there is free and smooth motion to the latitude and declination arcs; that the clamps are positive and the tangent motions smooth and free in either direction; that the eyepiece is carefully focused upon the cross wires; and that the objective is carefully focused upon any quite distant object, then secured in this position. The eyepiece turns freely and has a pin which travels in a guide slot; this pin is not a clamp. The objective may be moved by first loosening, then pushing the screw which will be found to travel in a guide slot near the lower (or left hand) collar bearing.

ADJUSTMENTS.

The field adjustments of the solar attachment should be considered in the following order:

1. The equatorial wires must be made parallel to the axis of the reflector.
2. The line of sight of the auxiliary telescope must lie in its true turning axis.
3. The polar axis, or line of sight of the auxiliary telescope, must be normal to the axis of the latitude arc, describe a true vertical plane when turning on said axis, and said vertical plane must be parallel to the vertical plane of the transit telescope.
4. The latitude arc should read zero when the auxiliary telescope is horizontal.
5. The declination arc should at all times read the true declination of the sun plus the refraction in polar distance.
6. The hour circle should read the sun's apparent time.

There are two or more methods of testing each and every adjustment, but those stated below are without doubt the simplest, and most rapid and reliable of all field methods. The true meridian should be established by Polaris or other independent observation, upon which to test the solar, but otherwise it plays only a small part in the adjustments of the solar attachment. The true latitude of the station must be definitely known. There should be a clear view to a distant object in the horizon, but if an object less than a mile away must be utilized due allowance may be made for the horizontal distance between the vertical planes of the transit and auxiliary telescopes.

1. *The equatorial wires.*—Set up the instrument as in a regular solar observation, setting off the known latitude, declination and apparent time, and bring the sun's image accurately between the equatorial wires by orienting the transit approximately to the meridian, in which position the instrument should be clamped. (See fig. 1.) Turn the auxiliary telescope in hour angle, causing the sun's image to travel across the field from side to side. If the image follows the equatorial wires accurately the latter are parallel to the axis of the reflector as required. If the sun's image departs materially from the equatorial wires, the capstan screws which hold the diaphragm should be loosened and the reticle may be rotated until the equatorial wires are made to agree with the path of the sun's image across the field, then return each capstan screw to a proper seat.

2. *Collimation of the auxiliary telescope.*—Swing the mirror to give a direct view through the auxiliary telescope. Set the line of sight on a distant point and clamp the instrument. Revolve the auxiliary telescope 12 hours in hour angle. If the line of sight remains fixed on the distant point it agrees with the turning axis as required. If after revolution, the line of sight appears to be above or below, or to the right or left, of the distant point, one-half of the differences should be taken up with the capstan screws which control the diaphragm. The test should be repeated until the auxiliary telescope is in perfect collimation.

3. *The polar axis.*—Carefully level the transit and then sight the main telescope to the distant point and clamp the instrument; sight toward the same point with the auxiliary telescope, and place the strid-

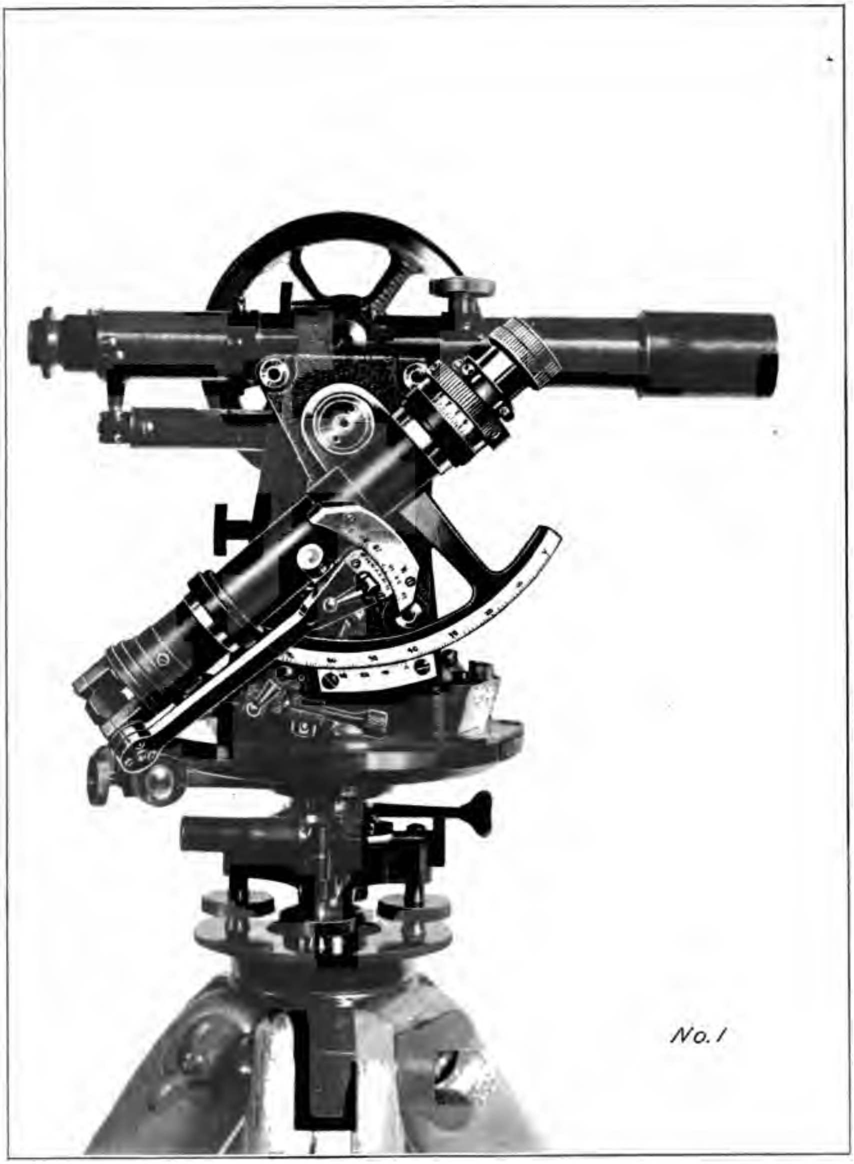

FIG. 1.—The solar transit as it appears in use.

ing level on the latitude axis. (See fig. 2.) The striding level should be reversed to see if there is any error in the level itself, and if so take the mean position for the true indication of the level. If the

latitude axis is not horizontal it may be made so by adjusting the lower pair of capstan nuts on the base frame of the solar attachment. If the line of sight of the auxiliary telescope is not parallel

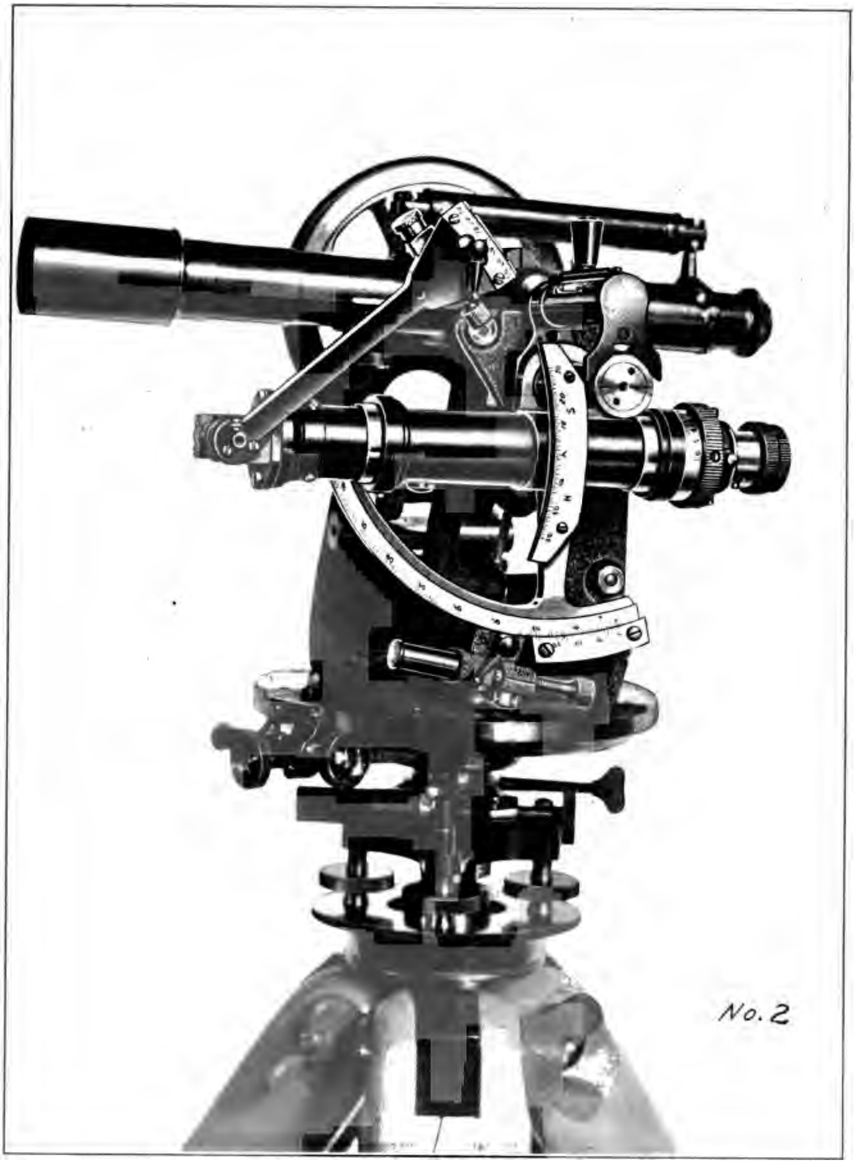

FIG. 2.—Direct sighting through the auxiliary telescope, with the mirror swung to a central position, and showing the striding level on the latitude axis.

to that of the main telescope it may be made parallel by means of the left-hand upper pair of capstan nuts on the base frame of the solar. After fulfilling the foregoing conditions turn the transit 180°

in azimuth and reverse both telescopes so as to sight again to the same distant object, setting the main telescope upon the object. (See fig 3.) If the auxiliary telescope does not again sight upon the distant

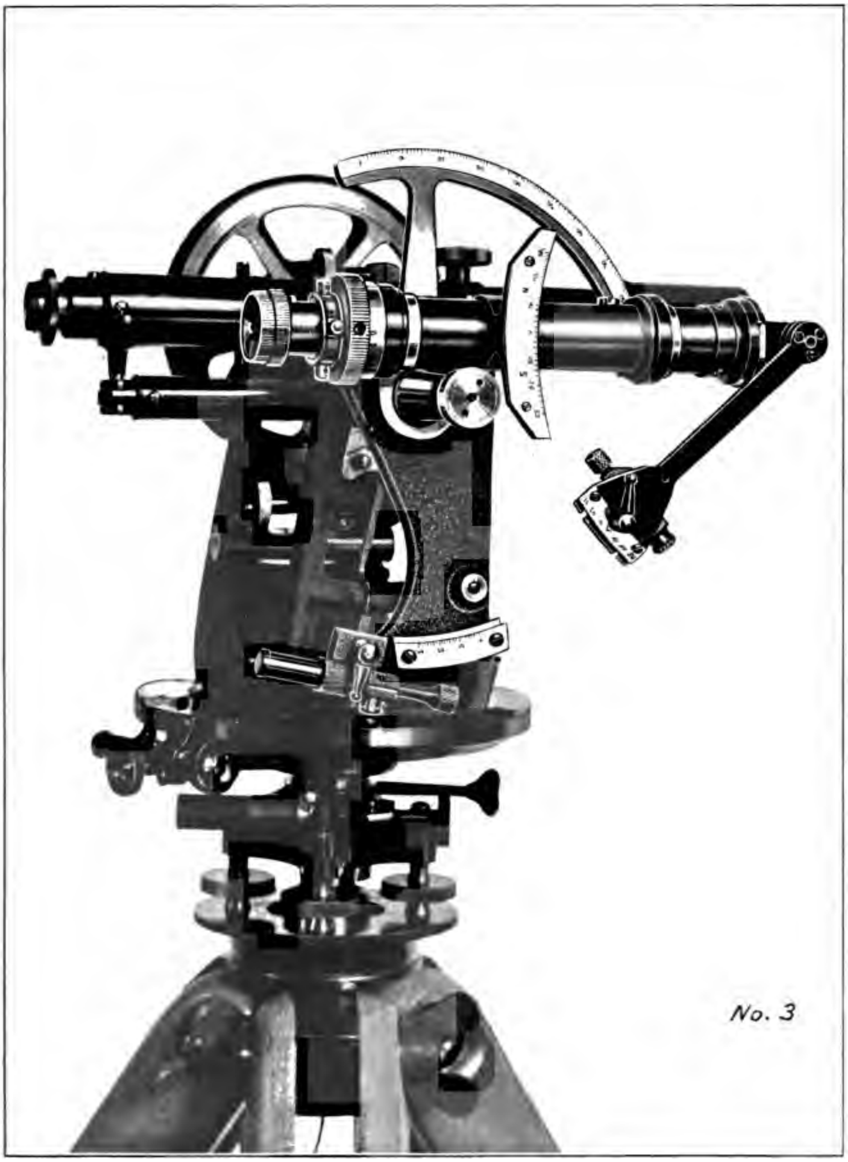

FIG. 3.—The auxiliary telescope in reversed position.

object, one-half the error is due to its line of sight not being at right angles to the axis of the latitude arc. Take up one-half of the amount of the error by means of the pair of capstan nuts at one end of the

auxiliary telescope, and take up the other half of the error by again correcting the left-hand upper pair of capstan nuts on the base frame of the solar. The line of sight of the auxiliary telescope should now be normal to the axis of the latitude arc, should describe a vertical plane when turning on said axis, and said vertical plane should be parallel to the vertical plane of the transit telescope. The tests should be carefully repeated until the adjustments are perfected.

4. *The latitude vernier.*—Carefully level the transit, clamp the latitude arc at zero, and place the striding level in position on the auxiliary telescope. (See fig. 4.) The striding level should be reversed to see if there is any error in the level itself, and if so take the mean position for the true indication of the level. If the auxiliary telescope is not horizontal it may be made so by means of the tangent motion of the latitude arc. When the auxiliary telescope has been made truly horizontal the reading will indicate the index error of the vernier of the latitude arc. The vernier is held in position by two screws passing through elongated holes, and by loosening the screws the vernier may be shifted to read zero, or the difference from zero may be carried as an index error.

5. *The declination vernier.*—A few minutes before apparent noon set the instrument in the established meridian. Set off the known true latitude, allowing for any index error in the vernier of the latitude arc. Carefully level the transit and clamp the instrument with the main telescope in the meridian. Bring the sun's image into the field of the auxiliary telescope by turning this telescope in hour angle. At apparent noon bring the sun's image accurately between the equatorial wires by means of the tangent motion of the declination arc. The difference between the reading of the declination arc and the calculated declination (corrected for refraction) will indicate the index error of the vernier of the declination arc. This vernier is also held in position by two screws passing through elongated holes and by loosening the screws the vernier may be shifted to read the calculated declination for apparent noon of that date, or the difference may be carried as an index error. This test should be made every day the instrument is used. If by some failure in the adjustments of the solar attachment a difference of as much as 30″ from previous tests should be discovered in the noon observation, the new error will generally be found in one of three places: (a) The auxiliary telescope may be out of collimation; (b) the vernier of the latitude arc may have become loose and shifted; or (c) the vernier of the declination arc may have become loose and shifted. Any slight error in the other adjustments, or in the determination of the established meridian, will not appear in the noon test of the declination arc.

6. *The hour circle.*—A few minutes before apparent noon set the instrument in the established meridian. Level the transit and clamp the instrument with the main telescope in the meridian and elevated

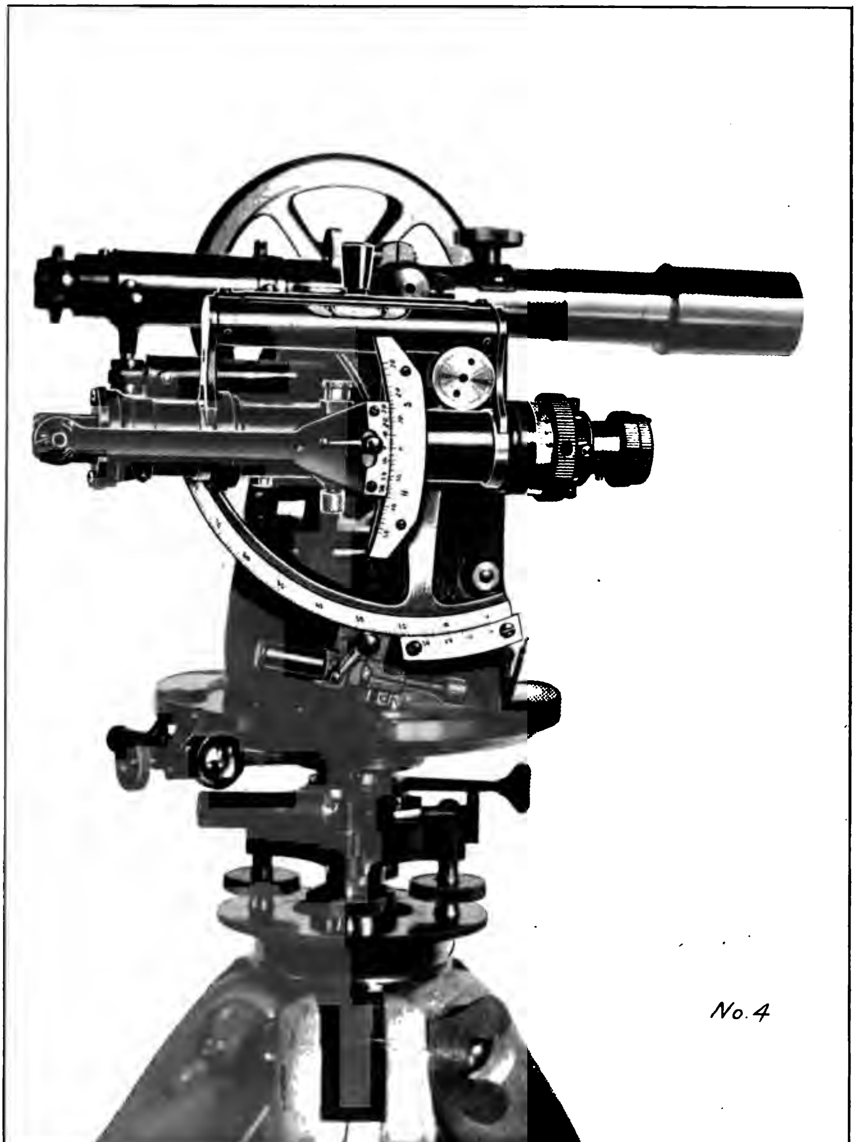

FIG. 4.—The striding level on the auxiliary telescope.

to the sun's altitude. Set your watch to read 12 o'clock as the sun's center crosses the vertical wire of the main telescope. At any convenient time thereafter set off the proper readings on the latitude

and declination arcs, and with the instrument in the meridian, bring the sun's image to the center of the field of the auxiliary telescope and observe the watch time. If the reading of the hour circle agrees with the watch it is in adjustment; if not, it may be made to read apparent time by loosening the set screw which holds the hour circle in position and shifting the circle until the reading agrees with the watch, care being taken not to move the auxiliary telescope in hour angle until after the set screw is again seated. The test may then be repeated as often as desirable.

USE OF THE SOLAR ATTACHMENT.

Before using the solar attachment the latitude of the station and the sun's declination (properly corrected for refraction in polar distance) must be known and accurately set off on the respecitve arcs. The instrument is carefully leveled and the apparent time set off on the hour circle. The transit is then oriented to the meridian. The plates are generally first set to zero and the sun's image brought into the field of the solar telescope before setting the lower clamp; thereupon the sun's image is brought accurately between the equatorial wires with the lower tangent motion; this gives the solar meridian. The transit may then be used for any normal function. The solar meridian may be tested as many times as may be desirable by simply setting the plates back to zero and turning the auxiliary telescope in hour angle to the apparent time; this brings the sun's image again to the center of the field. The sun's declination is constantly changing at a very slow rate, so that it is necessary to correct the reading on the declination arc with its tangent motion to agree with the declination of the sun for the apparent time of observation.

The great advantage of the Smith solar over all other forms of solar attachment is found in the fact that the latitude and declination arcs remain clamped while the transit is being used in any normal function. Upon setting up at a second station it is necessary merely to correct the latitude and declination arcs with their tangent motions to agree with any change from the previous station. For this reason it may be operated more rapidly than any other form of solar attachment. In fact, the solar meridian is so quickly determined that the observation is usually repeated at every station.

The same restrictions which must be recognized in making direct observations on the sun operate in the same way as a prohibition in the use of any solar instrument. There are only two such restrictions: (1) when the sun is within two hours, or possibly an hour and one-half, of the meridian; and (2) when the sun is low in the horizon. In the first instance the sun's relative rate of change in azimuth is much greater than the rate of change in altitude, and a small error in adjustment or in setting the arcs is greatly multiplied. In the